CLAIMS

What is claimed is:

1. A method of treating a patient suffering from thrombosis, the method comprising:

positioning a single ultrasound probe proximate a body surface of the patient;

in a diagnostic mode, administering pulsed ultrasound from the single probe to the patient at a first frequency for a first period of time; and

in a therapeutic mode, administering ultrasound from the single probe to the patient at a second frequency for a second period of time to enhance a thrombolytic action of a thrombolytic agent.

2. The method of claim 1, further comprising externally administering the thrombolytic agent into the patient prior to administering the ultrasound in the therapeutic mode.

3. The method of claim 1, further comprising externally administering the thrombolytic agent, the thrombolytic agent comprising tissue plasminogen activator (t-PA), recombinant t-PA (rt-PA), TNK tPA, urokinase, or streptokinase.

4. The method of claim 1 wherein the thrombolytic agent comprises a naturally occurring agent in the patient.

5. The method of claim 1 wherein the ultrasound administered in the therapeutic mode comprises pulsed or continuous-wave ultrasound.

6. The method of claim 1 wherein the first frequency is different from the second frequency.

7. The method of claim 1 wherein the first and second frequencies comprise a substantially 2 MHz frequency.

8. The method of claim 1 wherein the first frequency comprises a substantially 2 MHz frequency, and the second frequency comprises a frequency substantially between 1 MHz and 3 MHz.

9. The method of claim 1 wherein the second frequency comprises a frequency below 200 kHz.

10. The method of claim 1 wherein administering ultrasound in the diagnostic and therapeutic modes is controlled by a computer.

11. The method of claim 1 wherein administering ultrasound in the diagnostic and therapeutic modes occurs simultaneously.

12. The method of claim 1 wherein the second period of time is greater than the first period of time.

13. The method of claim 1 wherein administering ultrasound in the diagnostic and therapeutic modes comprises applying ultrasound to a cranial region of the patient.

14. The method of claim 1 wherein administering ultrasound in the diagnostic and therapeutic modes comprises applying ultrasound to a region of the leg of the patient.

15. The method of claim 1 wherein administering ultrasound in the diagnostic and therapeutic modes comprises applying ultrasound to the heart of the patient.

16. The method of claim 1 wherein administering ultrasound in the diagnostic and therapeutic modes comprises applying ultrasound to the pulmonary artery of the patient.

17. The method of claim 1 wherein the ultrasound is administered from the single probe in the diagnostic and therapeutic modes having a derated spatial peak temporal average intensity less than 720 mW/cm^2 in water.

18. The method of claim 1 wherein administering ultrasound in the therapeutic mode comprises administering ultrasound having an spatial peak temporal average intensity less than 50 mW/cm^2 at a middle cerebral artery.

19. The method of claim 1 wherein administering ultrasound comprises intermittently transmitting a signal having a substantially sinusoidal waveform.

20. The method of claim 1 wherein ultrasound in the diagnostic and therapeutic modes is administered intermittently.

21. The method of claim 1, further comprising administering a ultrasound in the therapeutic mode with a wider beam profile than the pulsed ultrasound administered in the diagnostic mode.

22. The method of claim 1, further comprising repeating administration of the ultrasound in the diagnostic and therapeutic modes until thrombosis is substantially eliminated.

23. The method of claim 1, further comprising:

selecting a region on a body surface of the patient;

defining a plurality of areas within the region;

administering the pulsed ultrasound to a first one of the areas during the diagnostic mode and evaluating a window through that first area;

if the window through the first area is not an optimum window, administering the pulsed ultrasound to a second one of the areas in the diagnostic mode and evaluating a window through the second area, at least a portion of the second area including at least a portion of the one area; and

repeating the administering the pulsed ultrasound to another area in the diagnostic mode if prior areas administered with pulsed ultrasound do not substantially include the optimum window, until an area having substantially the optimum window is located.

24. The method of claim 23 wherein defining a plurality of areas comprises placing on the body surface an ultrasound probe having a plurality of transducer elements arranged in an array, the array defining an area corresponding to the region.

25. The method of claim 24 wherein each of the transducer elements is triangular shaped, and the area is hexagonal shaped.

26. The method of claim 24 wherein each of the transducer elements is rectangular shaped, and the area is polygonal shaped.

27. The method of claim 23 wherein administering ultrasound and repeating the administering are controlled by a computer.

28. The method of claim 1, further comprising:

selecting a region on a body surface of the patient;

defining a plurality of areas within the region;

administering the pulsed ultrasound to a first one of the areas during the diagnostic mode and evaluating a window through that first area;

if the window through the first area is not an optimum window, administering the pulsed ultrasound to a second one of the areas in the diagnostic mode and evaluating a window through the second area, at least a portion of the second area including at least a portion of the first area;

repeating administering the pulsed ultrasound to another area in the diagnostic mode if prior areas administered with pulsed ultrasound do not substantially include the optimum window, until an area having substantially the optimum window is located; and

administering ultrasound in the therapeutic mode through the area having substantially the optimum window.

29. The method of claim 28 wherein defining a plurality of areas comprises placing on the body surface an ultrasound probe having a plurality of transducer elements arranged in an array, the array defining an area corresponding to the region.

30. The method of claim 29 wherein each of the transducer elements is triangular shaped, and the area is hexagonal shaped.

31. The method of claim 29 wherein each of the transducer elements is rectangular shaped, and the area is polygonal shaped.

32. The method of claim 28 wherein administering the pulsed ultrasound in the diagnostic mode, repeating the administering, and administering ultrasound in the therapeutic mode are controlled by a computer.

33. A method of treating a patient suffering from thrombosis, the method comprising:

positioning a single ultrasound probe proximate a body surface of the patient, the single probe having a diagnostic mode and a therapeutic mode;

in the diagnostic mode, administering a diagnostic ultrasound from the single probe to the patient at a first frequency ; and

in the therapeutic mode, administering therapeutic ultrasound from the single probe to the patient at a second frequency to enhance a thrombolytic action of a thrombolytic agent.

34. The method of claim 33 wherein the diagnostic and therapeutic ultrasound are administered simultaneously.

35. The method of claim 33 wherein the therapeutic ultrasound is administered for a period of time greater than the diagnostic ultrasound.

36. The method of claim 33 wherein administering the diagnostic and therapeutic are intermittently repeated.

37. The method of claim 33 wherein positioning the single ultrasound probe comprises:

mounting the single ultrasound probe on to a headframe device, the headframe device having a movable mount structured to allow the single ultrasound probe to be positioned at a plurality of different orientations with respect to the body surface of the patient; and

attaching the headframe on to a cranial region of the patient.

38. The method of claim 33 wherein the single ultrasound probe comprises a first crystal superimposed over a second crystal and wherein the first frequency is administered from the first crystal in the diagnostic mode and the second frequency is administered from the second crystal in the therapeutic mode.

39. The method of claim 33 wherein the single ultrasound probe comprises an outer element annularly arranged around an inner element and wherein the second frequency is administered from the inner element in the therapeutic mode and the first frequency is administered from the inner and outer elements in the diagnostic mode.

40. The method of claim 33 wherein the single ultrasound probe comprises a plurality of transducer elements arranged in an array, the array defining an area.

41. The method of claim 40 wherein each of the transducer elements is triangular shaped, and the area is hexagonal shaped.

42. The method of claim 40 wherein each of the transducer elements is rectangular shaped, and the area is polygonal.

43. The method of claim 40 wherein the plurality of transducer elements comprises 128 transducer elements.

44. The method of claim 40 wherein administering ultrasound in the diagnostic and therapeutic modes is controlled by a computer.

45. The method of claim 33, further comprising providing information to a user concerning blood flow by displaying graphical information depicting blood flow at a plurality of locations along a beam axis of the pulsed ultrasound.

46. The method of claim 33, further comprising providing information to a user concerning blood flow by:

displaying first graphical information depicting blood flow at a plurality of locations along a beam axis of the pulsed ultrasound; and

displaying second graphical information depicting blood flow velocities at a selected one of the locations, the first and second graphical information being displayed simultaneously.

47. A method of treating a patient suffering from thrombosis, the method comprising:

selecting a region on a body surface of the patient;

placing on the body surface a single ultrasound probe having a plurality of transducer elements arranged in an array, the array defining a plurality of areas within the region;

administering pulsed ultrasound from the ultrasound probe to a first one of the areas during a diagnostic mode and evaluating a window through that first area;

if the window through the first area is not an optimum window, administering the pulsed ultrasound to a second one of the areas in the diagnostic mode and evaluating a window

through the second area, at least a portion of the second area including at least a portion of the first area;

repeating the administration of the pulsed ultrasound to another area in the diagnostic mode if prior areas administered with pulsed ultrasound do not substantially include the optimum window, until an area having substantially the optimum window is located; and

administering the ultrasound in the therapeutic mode from the single ultrasound probe through the area having substantially the optimum window.

48. The method of claim 47 wherein the ultrasound administered in the therapeutic mode comprises pulsed or continuous-wave ultrasound.

49. The method of claim 47 wherein each of the transducer elements is triangular shaped, and the area is hexagonal shaped.

50. The method of claim 47 wherein each of the transducer elements is rectangular shaped, and the area is polygonal shaped.

51. The method of claim 47 wherein administering the pulsed ultrasound in the diagnostic mode comprises administering the pulsed ultrasound at a frequency different from a frequency of the ultrasound administered in the therapeutic mode.

52. The method of claim 47 wherein the ultrasound in the therapeutic mode is administered simultaneously with the pulsed ultrasound of the diagnostic mode.

53. The method of claim 47 wherein administering the pulsed ultrasound in the diagnostic mode, repeating the administering, and administering ultrasound in the therapeutic mode are controlled by a computer.

54. The method of claim 47, further comprising administering a thrombolytic agent to the patient and enhancing a thrombolytic action of the thrombolytic agent in the therapeutic mode.

55. The method of claim 47 wherein evaluating the window through the first area comprises providing information to a user concerning blood flow by displaying graphical information depicting blood flow at a plurality of locations along a beam axis of the pulsed ultrasound.

56. The method of claim 47 wherein evaluating the window through the first area comprises providing information to a user concerning blood flow by:

displaying first graphical information depicting blood flow at a plurality of locations along a beam axis of the pulsed ultrasound; and

displaying second graphical information depicting blood flow velocities at a selected one of the locations, the first and second graphical information being displayed simultaneously.

57. The method of claim 47 wherein the ultrasound is administered from the single probe in the diagnostic and therapeutic modes having a derated spatial peak temporal average intensity less than 720 mW/cm^2.

58. The method of claim 47 wherein administering ultrasound in the diagnostic and therapeutic modes comprises applying ultrasound to a cranial region of the patient.

59. The method of claim 47 wherein administering ultrasound in the diagnostic and therapeutic modes comprises applying ultrasound to a region of the leg of the patient.

60. The method of claim 47 wherein administering ultrasound in the diagnostic and therapeutic modes comprises applying ultrasound to the heart of the patient.

61. The method of claim 47 wherein administering ultrasound in the diagnostic and therapeutic modes comprises applying ultrasound to the pulmonary artery of the patient.

62. The method of claim 47 wherein administering the ultrasound in the therapeutic mode comprises administering a pulsed ultrasound having a spatial peak temporal average intensity of less than 50 mW/cm^2 at a middle cerebral artery.

63. An apparatus to treat a patient suffering from thrombosis, the apparatus comprising:

a single ultrasound probe structured to transmit pulsed ultrasound in a diagnostic mode, and ultrasound in a therapeutic mode, the ultrasound having a characteristic in the therapeutic mode that is different from a characteristic of the pulsed ultrasound in the diagnostic mode; and

a controller structured to switch the single ultrasound probe between the diagnostic and therapeutic modes and to process ultrasound Doppler signals returned by the single ultrasound probe during the diagnostic mode.

64. The method of claim 63, further comprising a headframe device structured to be worn on the head of a patient and having a movable mount onto which the single ultrasound probe is mounted, the movable mount structured to allow the single ultrasound probe to be positioned at a plurality of different orientations with respect to the body surface of the patient.

65. The apparatus of claim 63 wherein the single ultrasound probe comprises two transducer elements.

66. The apparatus of claim 65 wherein the two transducer elements comprise a first crystal and a second crystal, respectively, the first crystal superimposed on the second crystal, and the single ultrasound probe structured to transmit a first frequency from the first crystal in the diagnostic mode and to transmit a second frequency different from the first frequency from the second crystal in the therapeutic mode.

67. The apparatus of claim 65 wherein the two transducer elements comprise an outer element and an inner element, the outer element annularly arranged over the inner element, and the single ultrasound probe structured to transmit ultrasound from the inner element in the therapeutic mode and to transmit the pulsed ultrasound from the inner and outer elements in the diagnostic mode.

68. The apparatus of claim 63 wherein the single ultrasound probe comprises plurality of transducer elements arranged in an array, the array defining an area.

69. The apparatus of claim 68 wherein each of the transducer elements is triangular shaped, and the area is hexagonal shaped.

70. The apparatus of claim 68 wherein each of the transducer elements is rectangular shaped, and the area is polygonal.

71. The apparatus of claim 68 wherein the plurality of transducer elements comprises 128 transducer elements.

72. The apparatus of claim 63, further comprising a graphical display responsive to the controller and coupled to the single ultrasound probe, the graphical display having a blood locator display structured to depict a plurality of locations along an ultrasound beam axis at which blood flow is detected, the blood locator display responsive to the controller to depict the plurality of locations during the diagnostic mode based on the Doppler signals.

73. The apparatus of claim 72 wherein the graphical display further comprises:

a location indicator to identify a selected one of the plurality of locations; and

a spectogram to depict detected blood flow velocities as a function of time at the selected location.

74. The apparatus of claim 63 wherein the controller is structured to drive the single ultrasound probe to transmit a pulsed ultrasound in both the therapeutic and diagnostic modes at a substantially 2 MHz frequency.

75. The apparatus of claim 63 wherein the controller is structured to drive the single ultrasound probe to transmit a pulsed or continuous-wave ultrasound in the therapeutic mode.

76. The apparatus of claim 63 wherein the controller is structured to drive the single ultrasound probe to transmit a pulsed or continuous-wave ultrasound in the therapeutic mode for a period of time greater than a period of time to transmit the pulsed ultrasound in the diagnostic mode.

77. The apparatus of claim 63 wherein the controller is structured to drive the single ultrasound probe to transmit ultrasound in the therapeutic and diagnostic modes simultaneously.

78. The apparatus of claim 63 wherein the single ultrasound probe is structured to transmit a pulsed or continuous-wave ultrasound in the therapeutic mode with a beam profile wider than a beam profile of the pulsed ultrasound in the diagnostic mode.

79. A computer-readable medium whose contents configure a computer system to control treatment of a patient with ultrasound during a therapeutic mode and to provide information concerning blood flow detected by processing Doppler ultrasound signals along an ultrasound beam axis during a diagnostic mode by:

controlling transmission of the ultrasound during the diagnostic and therapeutic modes through a single probe;

determining blood flow at a plurality of locations along a beam axis of the pulsed ultrasound during the diagnostic mode; and

locating an optimum window through which to transmit the ultrasound in the therapeutic mode according to the blood flow.

80. The computer-readable medium of claim 79 whose contents further configure the computer system by displaying graphical information depicting the blood flow, and using the displayed graphical information to locate the optimum window through which to transmit the ultrasound in the therapeutic mode.

81. The computer-readable medium of claim 79 whose contents further configure the computer system by controlling the single ultrasound probe to transmit the ultrasound in the therapeutic mode at a frequency different than a frequency of the pulsed ultrasound in the diagnostic mode.

82. The computer-readable medium of claim 79 whose contents further configure the computer system by controlling the single ultrasound probe to transmit the ultrasound in the therapeutic mode for a time period greater than a time period of the pulsed ultrasound in the diagnostic mode.

83. The computer-readable medium of claim 79 whose contents further configure the computer system by controlling the single ultrasound probe to transmit the ultrasound in the therapeutic and diagnostic modes simultaneously.

84. The computer-readable medium of claim 79 whose contents further configure the computer system to control treatment and provide information by:

administering the pulsed ultrasound from the single ultrasound probe to a first one of a plurality of areas defining a region on a body surface of the patient during the diagnostic mode and evaluating a window through that first area;

if the window through the first area is not an optimum window, administering the pulsed ultrasound from the single ultrasound probe to a second one of the areas in the diagnostic mode and evaluating a window through the second area, at least a portion of the second area including at least a portion of the first area; and

repeating the administration of the pulsed ultrasound from the single ultrasound probe to another area in the diagnostic mode if prior areas administered with pulsed ultrasound do not

substantially include the optimum window, until an area having substantially the optimum window is located.

85. The computer-readable medium of claim 84 whose contents further configure the computer system by administering the ultrasound in the therapeutic mode from the single ultrasound probe through the area having substantially the optimum window.

86. The computer-readable medium of claim 79 whose contents further configure the computer system by transmitting either pulsed or continuous-wave ultrasound in the therapeutic mode.